IN THE SPECIFICATION

Please amend the paragraphs of the specification as follows:

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[0004] In some wireless (e.g., CDMA) communication systems, a pilot may be transmitted from a transmitter unit (e.g., a terminal) to a receiver unit (e.g., a base station) to assist the receiver unit to perform a number of functions. For example, the pilot may be used at the receiver unit for synchronization with the timing and frequency of the transmitter unit, estimation of the channel response and the quality of the communication channel, coherent demodulation of data transmission, and so on. The pilot is typically generated based on a known data pattern (e.g., a sequence of all zeros) and using a known signal processing scheme (e.g., channelized with a particular channelization code and spread with a known spreading sequence).

On page 4:

[0019] FIGS. 6A and 6B are diagrams that graphically illustrate the processing of the data samples to derive estimates of pilot interference, in accordance with a specific implementation ~~of the invention~~;

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[0037] A receive (RX) data processor 256 then receives and decodes the demodulated data for each terminal to recover the user-specific data and messages transmitted by the terminal on the reverse link. The processing by demodulator 254 and RX data processor 256 is complementary to that performed by modulator [[214]] 216 and TX data processor [[212]] 214, respectively, at the terminal.

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[0038] FIG. 4 is a block diagram of an embodiment of a rake receiver 254a, which is capable of receiving and demodulating the reverse link modulated signals from a number of terminals 106. Rake receiver 254a includes one or more (L) sample buffers 408, one or more (M) finger processors 410, a searcher 412, and a symbol combiner 420. The embodiment in FIG. 4 shows all finger ~~processor~~ processors 410 coupled to the same symbol combiner 420.

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[0049] Each sample buffer 408 stores the received data samples and further provides the proper data samples to the appropriate processing units (e.g., finger processors 410 and/or searcher 412) at the appropriate time. In one design, each buffer 408 provides the data samples to a respective set of finger processors 410 assigned to process the multipaths in the received signal associated with the buffer. In another design, a number of buffers 408 provide data samples (e.g., in a time division multiplexed manner) to a particular finger processor that has the capability to process a number of multipaths in a time division multiplexed manner. Sample buffers 408a through 408*l* may also be implemented as a single buffer of the appropriate size and speed.

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[0051] For each reverse link transmitted modulated signal, $x_j(t)$, searcher 412 may provide a set of one or more time offsets, $t_{i,j,l}$, for a set of one or more multipaths found for that reverse link modulated signal (possibly along with the signal strength of each found multipath). The time offsets, $t_{i,j,l}$, provided by searcher 412 are relative to the base station timing or CDMA system time, and are related to the time offsets, $\hat{t}_{i,j,l}$, shown in equation (2) which are relative to the time of signal transmission.

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[0061] In an embodiment, the pilot interference estimation and cancellation and the data demodulation are performed in "bursts". For each burst (i.e., each processing cycle), a segment of data samples for a particular number of PN chips are processed to estimate the pilot interference due to a particular multipath. In a specific embodiment, each segment comprises data samples for one symbol period, which may be 64 PN chips for cdma2000. However, other segment sizes may also be used (e.g., for data symbols of other durations), and this is within the scope of the invention. As described below, the data demodulation may be performed in parallel and in a pipelined manner with the pilot interference estimation to increase processing throughput and possibly reduce the overall processing time.

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[0071] In an embodiment, multiplier 536 provides the estimated pilot interference due to the m-th multipath at the sample rate (e.g., 8x the chip rate) and with the timing phase of the m-th multipath. This allows the estimated pilot interferences for all multipaths (which have different time offsets that are typically not all aligned to the PN chip timing boundaries) to be accumulated at a higher time resolution. The estimated pilot interference, $I_{pilot,m}(k+\mathrm{N})$, for the m-th multipath, which includes the same number of interference samples as for the data sample segment, is then provided to an interference accumulator 538. As shown in FIG. 6A, the interference samples for the m-th multipath are stored (or accumulated with the interference samples already stored) at locations in the accumulator 538 determined by the fractional part of the multipath's time offset.

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[0079] A data demodulator 548 then receives and demodulates the data symbols with the pilot estimates, $P_m(k)$, to provide demodulated symbols (i.e., demodulated data) for the m-th multipath, which are then provided to symbol combiner 420. The data demodulation and symbol combining may be achieved as described in the aforementioned U.S Patent No. 5,764,687 patent. The '687 patent describes BPSK data demodulation for IS-95 by performing dot product between

the despread data and the filtered pilot. The demodulation of QPSK modulation, which is used in cdma2000 and W-CDMA, is ~~a straight forward~~ an extension of the techniques described in the '687 patent. That is, instead of dot product, both dot product and cross-product are used to recover the inphase and quadrature streams.

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[0080] As noted above, the data demodulation for the *m*-th multipath may be performed in parallel and in a pipelined manner with the pilot interference estimation. While despreader 544 and data channelizer 546 are processing the pilot-canceled data samples for the current segment (with the spreading sequence, $S_m^*(k)$, and the channelization code, $C_{ch,m}$) to provide the data symbols for the *m*-th multipath, despreader 524 and pilot channelizer 526 may process the same data samples for the current segment (with the spreading sequence, $S_m^*(k)$, and the pilot channelization code, $C_{pilot,m}$) to provide the pilot symbols for this multipath. The pilot symbols are filtered by pilot filter 528 to provide pilot estimates, $P_m(k)$, for the multipath. Pilot interference estimator 530 then derives the estimated pilot interference, $I_{pilot,m}(k+\mathrm{N})$, due to this multipath for the following segment, as described above. In this manner, while data demodulation is performed on the current segment using the total pilot interference, $I_{pilot}(k)$, derived from a prior segment, pilot interference for the next segment is estimated and stored to another section of the accumulator 538, to be used for the next segment.

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[0081] In an embodiment, the pilot for a particular multipath being demodulated is estimated based on the "raw" received data samples (from sample buffer 408x) as described above, and not based on the pilot-canceled data samples (from accumulator 538). In another embodiment, the pilot may be estimated based on the pilot-canceled data samples if the total pilot interference includes some or all of the interfering pilots except for the pilot of the multipath being demodulated (i.e., the pilot of the multipath being demodulated is included in the ~~pilot-canceled~~ "other pilots canceled" data samples). This alternative embodiment may provide an

improved estimate of the channel response of the multipath being demodulated, and is especially advantageous for the reverse link where the pilot estimation is typically the limiting factor in dealing with a weak multipath. The same "other pilots canceled" data samples that is used for pilot estimation may also be processed to recover the data for the multipath, which is advantageous for a finger processor architecture that performs both pilot estimation and data demodulation in parallel on the same data sample stream. The same concept may be used to estimate the channel response of a particular interfering multipath (i.e., the estimated channel response may be based on either the raw data samples or the "other pilots canceled" data samples having interfering pilots except for the pilot of that particular multipath removed).

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[0082] FIGS. 6A and 6B are diagrams that illustrate the processing of the data samples to derive estimates of pilot interference, in accordance with a specific implementation ~~of the invention~~. In the example shown in FIGS. 6A and 6B, the received signal includes three multipaths that are associated with time offsets of t_1, t_2, and t_3. The received signal is digitized at a sample rate that is 8 times the chip rate to provide data samples, which are stored to the sample buffer <u>408</u>. These multipaths may or may not be sampled at their peaks.

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[0084] In FIG. 6A, for the n-th symbol period for the m-th multipath with a fractional time offset of $t_{frac,m} = 5$, resampler 522 receives data samples 5 through 516 from the sample buffer <u>408</u> and provides to despreader 524 data samples 5, 13, 20, and so on, and 509, which are represented by the shaded boxes. Correspondingly, despreader 524 receives the spreading sequence, $S_m^*(k)$, with a phase corresponding to the same time offset of t_m, and despreads the decimated data samples with the spreading sequence. A pilot estimate, $P_m(k)$, is then derived based on the despread samples for this segment, as described above.

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[0085] To derive the estimated pilot interference due to the *m*-th multipath, spreader 534 receives the spreading sequence, $S_m(k+\mathrm{N})$, corresponding to the next segment and spreads channelized pilot data. Multiplier 536 then multiplies the spread pilot data (spread by spreading sequence, $S_m(k+\mathrm{N})$), with the pilot estimate, $P_m(k)$, derived from the current segment to provide the estimated pilot interference, $I_{pilot,m}(k+\mathrm{N})$, for the next segment. The estimated pilot interference, $I_{pilot,m}(k+\mathrm{N})$, comprises interference samples 517 through 1028, which are accumulated with the samples at the same indices 517 through 1028 in the interference accumulator 538, as shown in FIG. 6A. In this way, the fractional time offset of the *m*-th multipath is accounted for in the derivation of the total pilot interference.

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[0090] For the demodulator design in which the same data samples are processed multiple times (e.g., if one finger processor is assigned to process a number of multipaths), the sample buffer 408 may be designed and operated in a manner to ensure that the data samples are not inadvertently dropped. In an embodiment, the sample buffer is designed to receive incoming data samples while providing stored data samples to the finger processor(s). This may be achieved by implementing the sample buffer in a manner such that stored data samples may be read from one part of the buffer while new data samples are written into another part of the buffer. The sample buffer may be implemented as a double buffer or multiple buffers, a multi-port buffer, a circular buffer, or some other buffer design. The interference accumulator 538 may be implemented in similar manner as the sample buffer 408 (e.g., as a circular buffer).

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[0091] For the above demodulator design, to avoid overwriting samples that are still being processed, the capacity of the sample buffer 408 may be selected to be at least twice the time required to derive the total pilot interference for all M multipaths (with the relationship between time and buffer capacity being defined by the sample rate). If a different data sample segment may be used for each of the M multipaths, then the capacity of the sample buffer may be

selected to be at least $(2 \cdot N \cdot N_{os})$ for each received signal assigned to the sample buffer, where N is the duration of data samples used to derive the estimated pilot interference for one multipath and N_{os} is the oversampling factor for the data samples (which is defined as the ratio of the sample rate over the chip rate). For the above example in which a segment of one symbol period (e.g., N = 64 PN chips) is processed for each multipath, a buffer of two symbol periods would be able to provide a segment of one symbol period of data samples for each multipath regardless of its fractional time offset. And if the oversample rate is $N_{os} = 8$, then the minimum size of the buffer is $(2 \cdot N \cdot N_{os} = 2 \cdot 64 \cdot 8 = 1024)$ data samples.

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[0092] Similarly, the capacity of the interference accumulator 538 may be selected to be at least $(3 \cdot N \cdot N_{os})$. The extra symbol period for the interference accumulator (i.e., $3 \cdot N$ instead of $2 \cdot N$) is to account for the fact that the estimated pilot interference is derived for the next segment.

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[0095] FIG. 7 is a flow diagram of a process 700 to derive the total pilot interference for a number of multipaths, in accordance with an embodiment of the invention. Process 700 may be implemented by the finger processor 410 shown in FIG. 5.

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[0096] Initially, the accumulator 538 used to accumulate the estimated pilot interferences is cleared, at step 712. An interfering multipath that has not been processed is then selected, at step 714. Typically, the pilot interference is estimated for each multipath assigned for data demodulation. However, pilot interference due to unassigned multipaths may also be estimated. In general, any number of interfering multipaths may be processed, and these multipaths are those for which the pilot interference is to be estimated and accumulated to derive the total pilot interference.

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[0097] The data samples for the received signal with the selected multipath is then processed to derive an estimate of the channel response of the selected multipath, at step 716. The channel response may be estimated based on the pilot in the selected multipath, as described above. For cdma2000, this processing entails (1) ~~spreading~~ despreading the data samples with a spreading sequence for the multipath (i.e., with the proper phase corresponding to the time offset of the multipath), (2) channelizing the despread data samples to provide pilot symbols (e.g., multiplying the despread samples with the pilot channelization code and accumulating the channelized data samples over the pilot channelization code length), and (3) filtering the pilot symbols to derive pilot estimates that are indicative of the channel response of the selected multipath. Estimation of the channel response based on some other techniques may also be used, and this is within the scope of the invention.

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[0098] The pilot interference due to the selected multipath is then estimated, at step 718. The pilot interference may be estimated by generating processed pilot data and multiplying this data with the estimated channel response derived in step 716. The processed pilot data is simply the spreading sequence for the selected multipath if the pilot data is a sequence of all zeros and the pilot channelization code is also all zeros. In general, the processed pilot data is the pilot data after all signal processing at the transmitter unit but prior to the filtering and frequency upconversion (e.g., the data at the output of modulator 216a in FIG. 3 for the reverse link in cdma2000).

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[0099] The estimated pilot interference for the selected multipath is then accumulated in the interference accumulator 538 with the estimated pilot interferences for prior-processed multipaths, at step 720. As noted above, the timing phase of the multipath is observed in performing steps 716, 718, and 720.

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[00100] A determination is then made whether or not all interfering multipaths have been processed, at step 722. If the answer is no, then the process returns to step 714 and another interfering multipath is selected for processing. Otherwise, the content of the accumulator 538 represents the total pilot interference due to all processed ~~multipath~~ multipaths, which may be provided in step 724. The process then terminates.

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[00103] Initially, the total pilot interference due to all multipaths of interest is derived, at step 812. Step 812 may be implemented using process 700 shown in FIG. 7. A particular multipath is then selected for data demodulation, at step 814. In an embodiment and as described above, the total pilot interference is initially canceled from the selected multipath, at step 816. This may be achieved by subtracting the interference samples for the total pilot interference (which are stored in the accumulator 538) from the data samples for the received signal that includes the selected multipath.

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[00104] Data demodulation is then performed on the pilot-canceled signal in the normal manner. For cdma2000, this entails (1) despreading the pilot-canceled data samples, (2) channelizing the despread data to provide data symbols, and (3) demodulating the data symbols with the pilot estimates. The demodulated symbols (i.e., the demodulated data) for the selected multipath are then combined with the demodulated symbols for other multipaths for the same transmitter unit (e.g., terminal). The demodulated symbols for multipaths in multiple received signals (e.g., if receive diversity is employed) may also be combined. The symbol combining may be achieved by the symbol combiner 420 shown in FIG. 4.

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[00107] Referring back to FIGS. 4 and 5, searcher 412 may be designed and operated to search for new multipaths based on the pilot-canceled data samples (instead of the raw received data samples from buffers 408). This may ~~provided~~ provide improved search

performance since the pilot interference from some or all known multipaths may have been removed as described above.

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[00108] The pilot interference cancellation techniques described herein may be able to provide noticeable improvement in performance. The pilot transmitted by each terminal on the reverse link contributes to the total channel interference, I_o, in <u>a</u> similar manner as background noise, N_o. The pilots from all terminals may represent a substantial part of the total interference level seen by all terminals. This would then result in a lower signal-to-total-noise-plus-interference ratio (SNR) for the individual terminal. In fact, it is estimated that in a cdma2000 system (which supports pilots on the reverse link) operating near capacity, approximately half of the interference seen at a base station may be due to the pilots from the transmitting terminals. Cancellation of the pilot interference may thus improve the SNR of each individual terminal, which then allows each terminal to transmit at a lower power level and increase the reverse link capacity.

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[00113] The demodulator and other processing units that may be used to implement various aspects and embodiments of the invention may be implemented in hardware, software, firmware, or a combination thereof. For a hardware design, the demodulator (including the data demodulation unit and the elements used for pilot interference estimation and cancellation such as the pilot estimator and the pilot interference estimator), and other processing units may be implemented within one or more application specific integrated circuits (ASIC), digital signal processors (~~DSP~~ <u>DSPs</u>), digital signal processing devices (DSPDs), field programmable gate arrays (~~FPGA~~ <u>FPGAs</u>), processors, microprocessors, controllers, microcontrollers, programmable logic devices (PLD), other electronic units, or any combination thereof.